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**Urata et al.**

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(54) **SYSTEMS AND METHODS FOR ACHIEVING IMPROVED EYE SAFETY OF AN OPTICAL TRANSCEIVER**

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***H04B 10/00*** (2013.01)
***H04B 10/077*** (2013.01)
*H04B 10/035* (2013.01)
*H04B 10/073* (2013.01)

(52) **U.S. Cl.**
CPC .......... ***H04B 10/0779*** (2013.01); *H04B 10/035* (2013.01); *H04B 10/073* (2013.01)

(58) **Field of Classification Search**
CPC .................................................. H04B 2210/08
USPC .......................................................... 398/151
See application file for complete search history.

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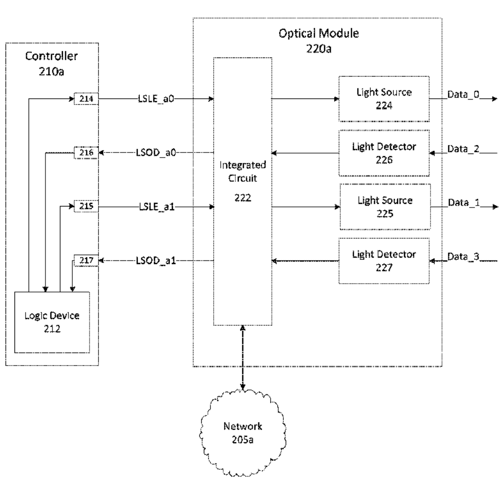
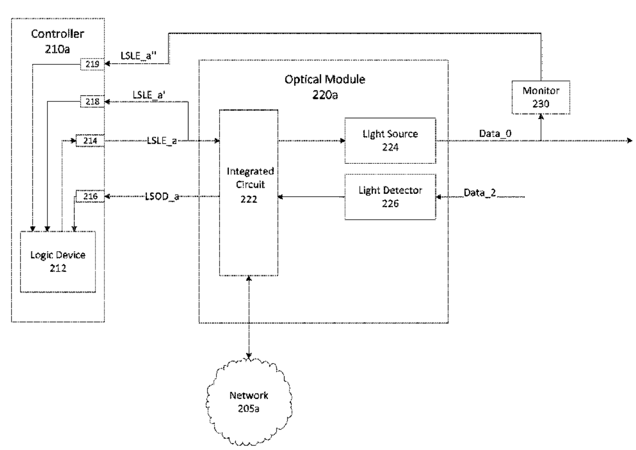
(57) **ABSTRACT**

Systems and methods for achieving eye safety of an optical transceiver are provided. An optical module can be configured to output a first optical signal. A first photodetector can be configured to output a signal indicative of a presence or absence of a second optical signal. A controller can be coupled to the optical module and the first photodetector and can be configured to control the output of the optical module. In response to a determination that an output of the first photodetector indicates the second optical signal is absent, the controller can control the optical module to output the first signal at a decreased average optical power. In response to a determination that an output of the first photodetector indicates the second optical signal is present, the controller can control the optical module to output the first signal at an increased average optical power.

**27 Claims, 8 Drawing Sheets**



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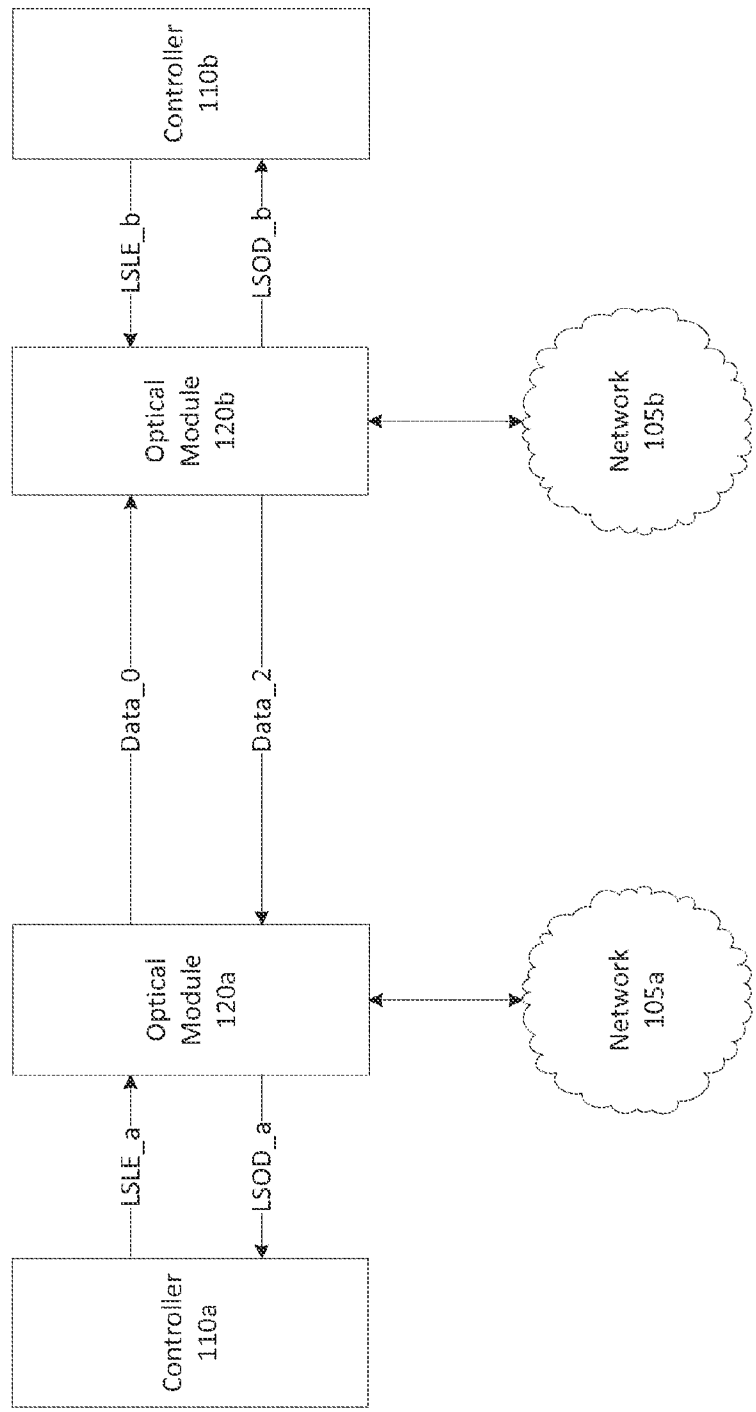


Figure 1A

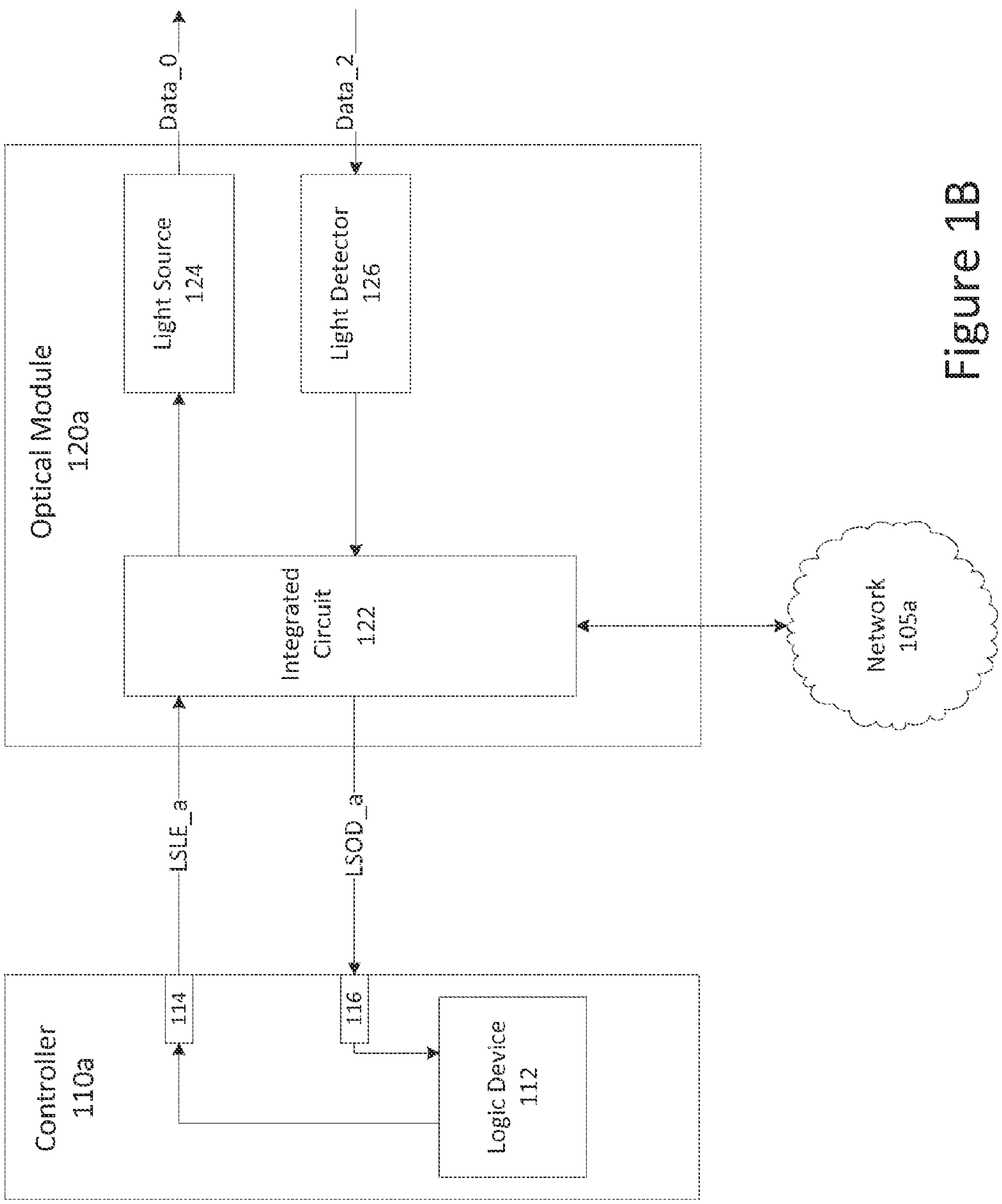
Controller
110a
114
116
Logic Device
112
LSLE_a
LSOD_a
Optical Module
120a
Integrated
Circuit
122
Light Source
124
Light Detector
126
Data_0
Data_2
Network
105a

Figure 1B

180

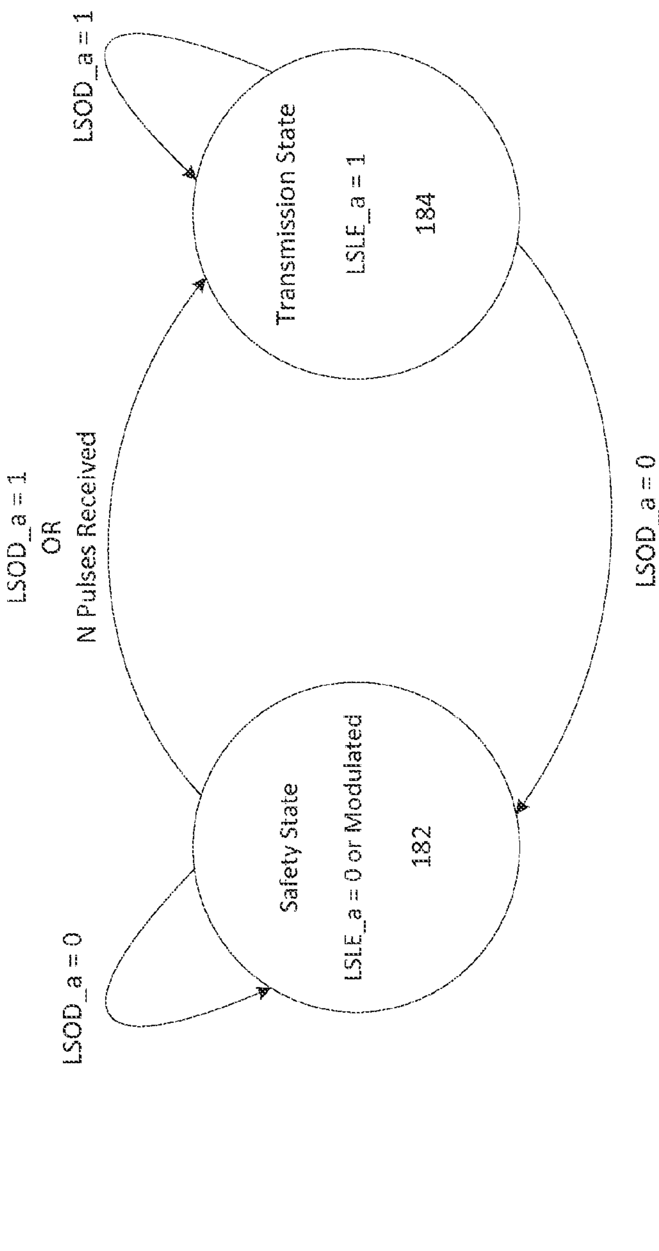


Figure 1C

200

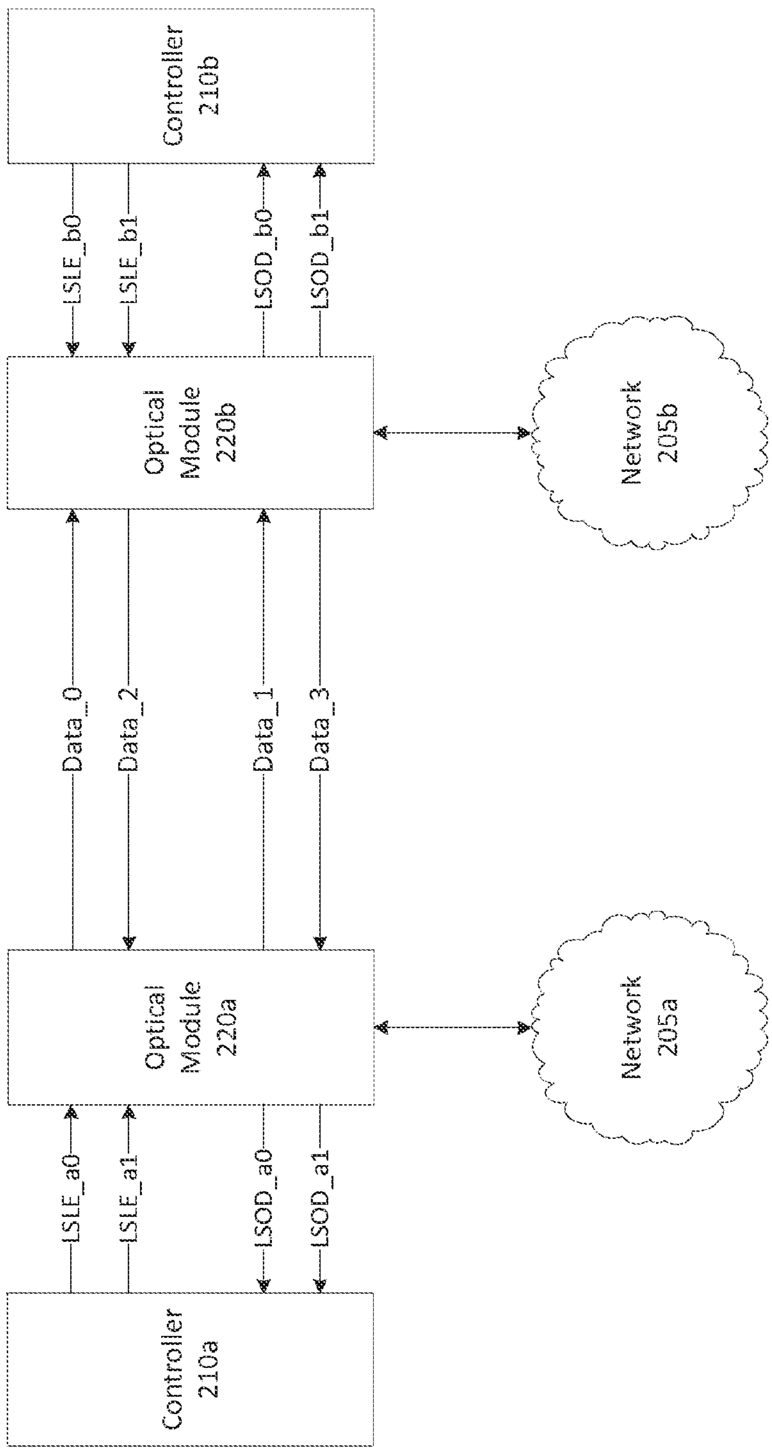


Figure 2A

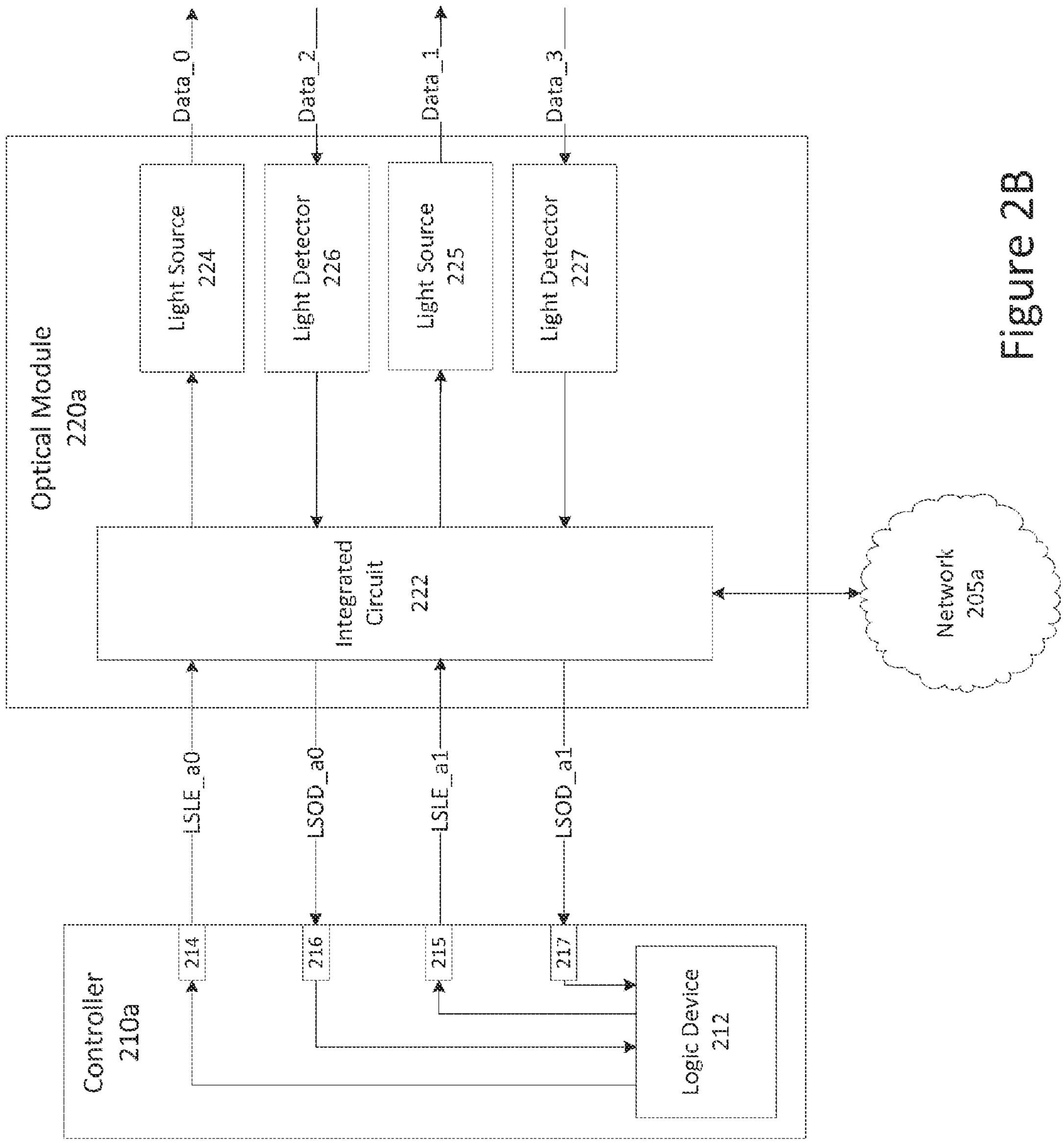
Data_0
Data_2
Data_1
Data_3
Optical Module
220a
Light Source
224
Light Detector
226
Light Source
225
Light Detector
227
Integrated
Circuit
222
Network
205a
LSLE_a0
LSOD_a0
LSLE_a1
LSOD_a1
Controller
210a
214
216
215
217
Logic Device
212

Figure 2B

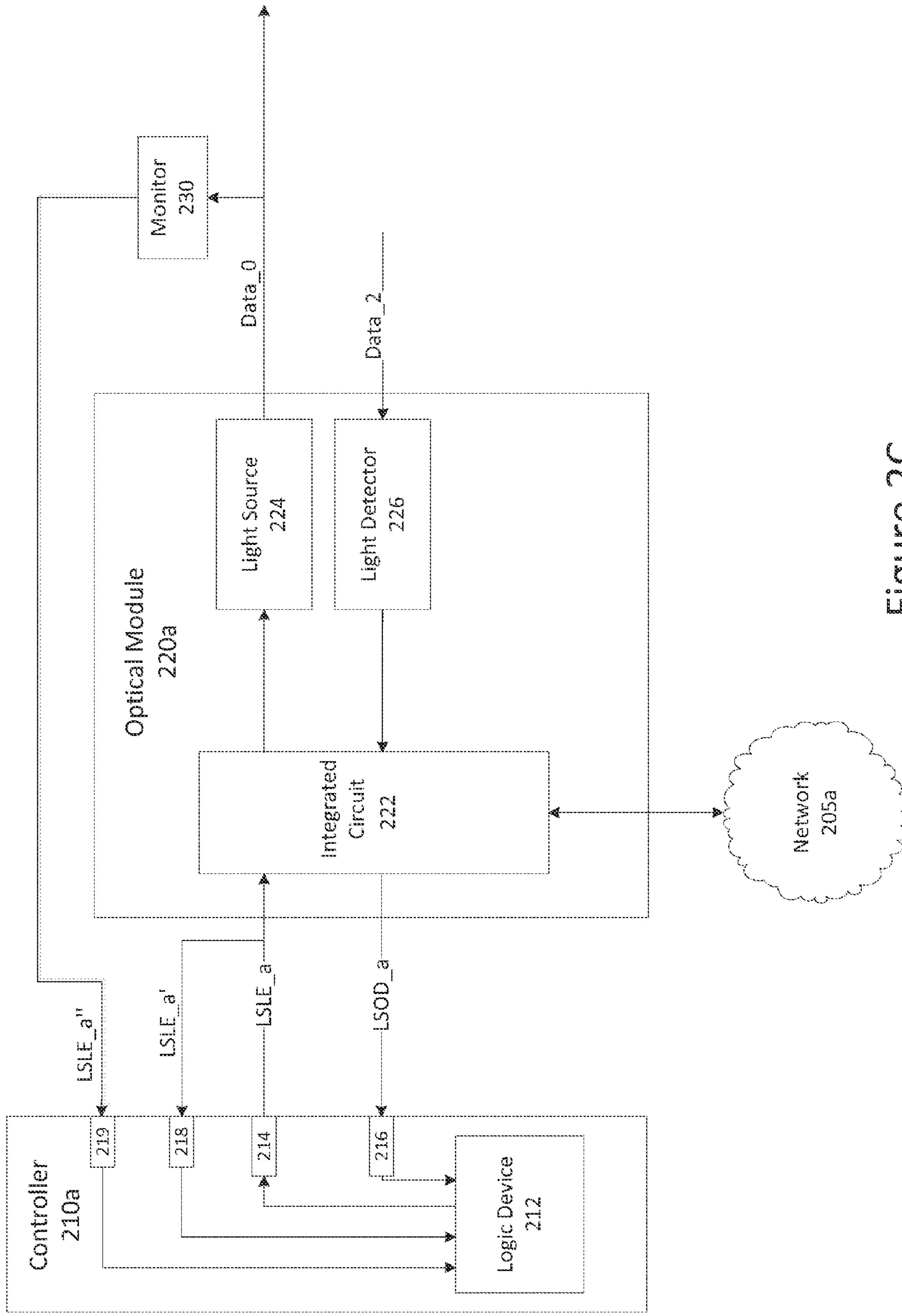
Monitor
230
Data_0
Data_2
Optical Module
220a
Light Source
224
Light Detector
226
Integrated
Circuit
222
Network
205a
LSLE_a''
LSLE_a'
LSLE_a
LSOD_a
Controller
210a
219
218
214
216
Logic Device
212

Figure 2C

280

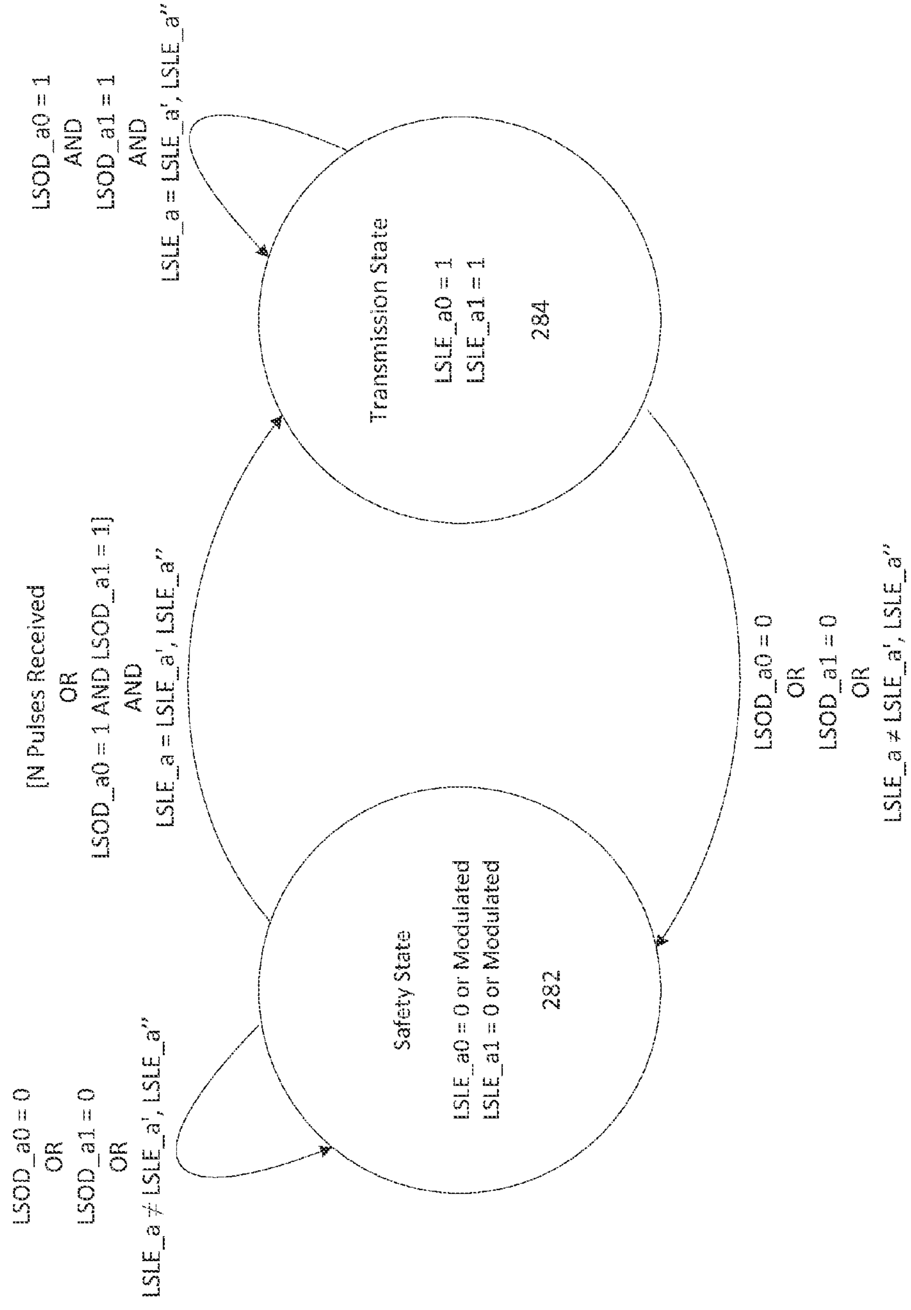


Figure 2D

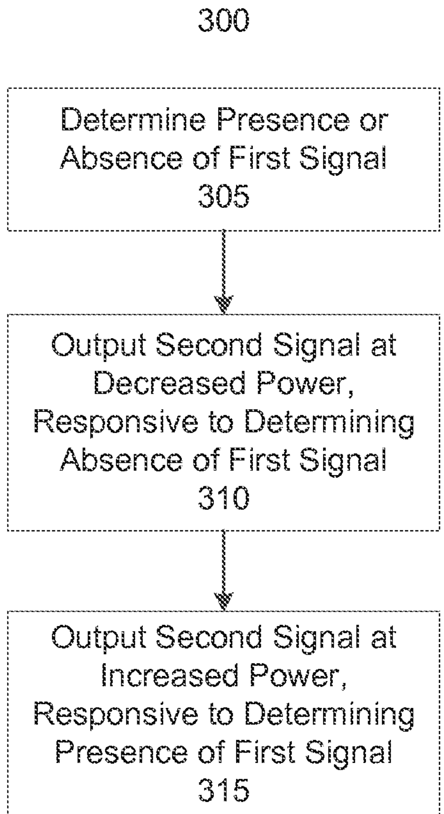
300
Determine Presence or Absence of First Signal
305
Output Second Signal at Decreased Power, Responsive to Determining Absence of First Signal
310
Output Second Signal at Increased Power, Responsive to Determining Presence of First Signal
315

FIG. 3

# SYSTEMS AND METHODS FOR ACHIEVING IMPROVED EYE SAFETY OF AN OPTICAL TRANSCEIVER

## BACKGROUND

An optical transceiver can include a laser for transmitting light. Some transceivers also include a lens that collimates the light into a beam. When a transceiver is connected to a fiber optic cable, the light from the transceiver is directed through the lens and into the fiber optic cable. However, if the cable is disconnected, light can escape from the transceiver and the eyes of a user or bystander can be exposed to the laser light. The optical power required for transmitting light in a transceiver, when collimated through the lens, can be harmful to the eye, resulting in such transceivers being assigned relatively high laser eye safety classifications. Individuals who install or repair such a transceiver are therefore required to wear safety goggles, receive training, and undergo periodic eye examinations.

## SUMMARY OF THE INVENTION

Aspects and implementations of the present disclosure are directed to systems and methods for achieving improved eye safety of an optical transceiver.

At least one aspect is directed to an optical transceiver. The transceiver can include an optical module configured to output a first optical signal. The transceiver can include a first photodetector configured to output a signal indicative of a presence or absence of a second optical signal. The transceiver can include an electronic processor coupled to the optical module and the first photodetector, and configured to control the output of the optical module. In response to a determination that an output of the first photodetector indicates the second optical signal is absent, the electronic processor can control the optical module to output the first signal at a decreased average optical power. In response to a determination that an output of the first photodetector indicates the second optical signal is present, the electronic processor can control the optical module to output the first signal at an increased average optical power.

At least one aspect is directed to a method for operating an optical transceiver. The method includes outputting, by a photodetector of the optical transceiver, a signal indicative of a presence or absence of a first optical signal. The method includes outputting, by the optical transceiver, a second optical signal at a decreased average optical power, responsive to a determination that the first optical signal is absent. The method includes outputting, by the optical transceiver, the second optical signal at an increased average optical power, responsive to a determination that the first optical signal is present.

At least one aspect is directed to an optical transceiver. The transceiver can include a light outputting means for outputting a first optical signal. The transceiver can include a light detecting means for outputting a signal indicative of a presence or absence of a second optical signal. The transceiver can include a signal analyzing means for analyzing the signal output by the light detecting means. The transceiver can include a signal controlling means. The signal controlling means can be configured to control the light outputting means to output the first optical signal at a decreased average optical power, responsive to a determination by the signal analyzing means that the output of the light detecting means indicates the second optical signal is absent. The signal controlling means also can be configured to control the light outputting means to output the first optical signal at an increased average optical power, responsive to a determination by the signal analyzing means that the output of the light detecting means indicates the second optical signal is present.



These and other aspects and embodiments are discussed in detail below. The foregoing information and the following detailed description include illustrative examples of various aspects and embodiments, and provide an overview or framework for understanding the nature and character of the claimed aspects and embodiments. The drawings provide illustration and a further understanding of the various aspects and embodiments, and are incorporated in and constitute a part of this specification.

## BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings are not intended to be drawn to scale. Like reference numbers and designations in the various drawings indicate like elements. For purposes of clarity, not every component may be labeled in every drawing.

FIG. **1**A is a block diagram of an example optical link, according to an illustrative implementation.

FIG. **1**B is a block diagram showing a controller and an optical module of the optical link shown in FIG. **1**A, according to an illustrative implementation.

FIG. **1**C is a state transition diagram implemented by the controller shown in FIG. **1**B, according to an illustrative implementation.

FIG. **2**A is a block diagram of an alternative example optical link, according to an illustrative implementation.

FIG. **2**B is a block diagram showing a controller and an optical module of the optical link shown in FIG. **2**A, according to an illustrative implementation.

FIG. **2**C is a block diagram showing an alternative configuration for a controller and an optical module of the optical link shown in FIG. **2**A, according to an illustrative implementation.

FIG. **2**D is a state transition diagram implemented by the controller shown in FIG. **2**B, according to an illustrative implementation.

FIG. **3** is a flow diagram of a process for operating an optical transceiver, according to an illustrative implementation.

## DESCRIPTION OF CERTAIN ILLUSTRATIVE IMPLEMENTATIONS

Following below are more detailed descriptions of various concepts related to, and implementations of, systems and methods for achieving eye safety of an optical transceiver. The various concepts introduced above and discussed in greater detail below may be implemented in any of numerous ways, as the described concepts are not limited to any particular manner of implementation. Examples of specific implementations and applications are provided primarily for illustrative purposes.

FIG. 1A is a block diagram of an example optical link **100**, according to an illustrative implementation. The optical link **100** can be used to reduce the risk of eye damage to an individual who is exposed to light sources of the optical link **100**. The optical link **100** can represent a communication channel of a computer network. For example, computing devices included in a first network **105*a*** can communicate with computing devices in a second network **105*b*** via the optical link **100**. The optical link **100** includes a first controller **110*a*** in communication with a first optical module **120*a***. A second controller **110*b*** communicates with a second optical module **120***b*. Network data, such as data from the networks **105***a* and **105***b*, can be exchanged between the first optical module **120***a* and the second optical module **120***b*.

The networks **105***a* and **105***b* can include computer networks such as portions of the Internet, personal, local, metro, wide or other area networks, intranets, satellite networks, and other communication networks such as voice or data mobile phone communication networks. In some implementations, the networks **105***a* and **105***b* can include servers in one or more data centers, and the optical link **100** can represent a communication channel within or between the data centers. For example, the optical modules **120***a* and **120***b* can be included in network interface cards of respective servers in the data centers or in various switches, hubs, or routers incorporated into the data centers.

The optical module **120***a* is configured to output an optical signal, shown as "Data **0**" in FIG. **1**A, to the optical module **120***b*. The optical module **120***b* outputs an optical signal shown as "Data_**2**," which is received by the optical module **120***a*.

In some implementations, the optical signals Data_**0** and Data_**2** are transmitted over fiber optic cables connected to respective input and output ports of the optical modules **120***a* and **120***b*. For example, the optical modules **120***a* and **120***b* can each include a controllable light source for generating and optical signal, as well as a light detector for receiving an optical signal. In some implementations, the Data_**0** and Data_**2** signals are carried by a single fiber optic cable. The optical signals Data_**0** and Data_**2** generated by the optical modules **120***a* and **120***b*, respectively, may be harmful to a human eye when the eye is exposed to the optical signals. For example, the optical power required to reliably transmit information between the optical module **120***a* and **120***b* may be relatively high to compensate for dispersion effects and optical noise within the fiber optic cable or electrical noise at the receiver/light detector. If the fiber optic cable carrying the Data_**0** signal is disconnected from the input port of the optical module **120***b*, individuals in the vicinity of the optical link **100** can be exposed to the light forming the Data_**0** signal that escapes from the end of the fiber optic cable, and the high optical power of the light may cause damage to the eyes of the individuals. A similar problem occurs when the fiber optic cable carrying the Data_**2** signal is disconnected from the optical module **120***a*, allowing light to escape from the optical link **100**.

To reduce the risk of eye damage, the controllers **110***a* and **110***b* can implement control algorithms that prevent their respective optical modules **120***a* and **120***b* from outputting unsafe light levels in circumstances in which individuals potentially might be exposed to harmful light that has escaped from the optical link **100** (e.g., due to a disconnected fiber optic cable). The controller **110***a* receives an optical detection signal, shown as LSOD_a, from the optical module **120***a* and outputs an enable signal, shown as LSLE_a, that is received by the optical module **120***a*. Likewise, controller **110***b* receives the optical detection signal LSOD_b from the optical module **120***b* and outputs the enable signal LSLE_b, which is received by the optical module **120***b*. In some implementations, the respective LSLE and LSOD signals are digital signals whose voltages correspond to logic levels. The details of the algorithm implemented by the controllers **110***a* and **110***b* is described further below in connection with FIGS. **1**B and **1**C.

FIG. **1**B is a block diagram showing a controller **110***a* and an optical module **120***a* of the optical link **100** shown in FIG. **1**A, according to an illustrative implementation. However, it should be appreciated that the controller **110***b* and the optical modules **120***b* include features similar to those shown in FIG. **1**B. The controller **110***a* includes a logic device **112**, an output interconnect **114**, and an input interconnect **116**. The logic device **112** receives the LSOD_a input signal from the input interconnect **116**. Based on the LSOD_a signal, the logic device **112** generates a voltage corresponding to the LSLE_a signal and outputs the voltage on the output interconnect **114**. In some implementations, the logic device **112** may be implemented as special purpose logic circuitry, such as a field programmable gate array (FPGA) or an application-specific integrated circuit (ASIC). In other implementations, the logic device **112** may be one or more general purpose processors configured to perform the processes disclosed herein by executing computer readable instructions stored on a computer readable medium.

The optical module **120***a* includes an integrated circuit **122**, a light source **124**, and a light detector **126**. The integrated circuit **122** can communicate with the network **105***a*, for example to receive network packets to be transmitted to another network node by the optical module **120***a* or to forward network packets intended for nodes on the network **105***a*. For example, the integrated circuit **122** may include, or may be communicatively coupled to, a network interface card (NIC), or any other interface device configured to transmit and receive information to and from the network **105***a*. The integrated circuit **122** controls the light source **124** to output the optical Data_**0** signal, which can be transmitted to another optical module such as the optical module **120***b* shown in FIG. **1**A. In some implementations, the light source **124** is a laser whose output can be controlled to correspond to the information encoded in the Data_**0** signal. Suitable lasers include typical semiconductor lasers found in traditional fiber optic communication devices. The light source **124** can also include lenses or other focusing devices to collimate light. Such collimation increases the efficiency with which the optical signal is coupled into a fiber optic cable, but increases the risk to the human eye. The integrated circuit **122** controls the light source **124** to generate the Data_**0** signal. In some implementations, the light source **124** is capable of outputting an optical signal, which, particularly when collimated through a lens, has a high average optical power that may harm the eyes of an individual whose eyes are exposed to the optical signal.

The integrated circuit **122** can use the LSLE_a signal as an enable input for the light source **124**. For example, when the LSLE_a signal has a logical high value, the integrated circuit **122** can control the light source **124** to transmit network data to the optical module **120***b* via the Data_**0** signal. The Data_**0** signal can correspond to network packets received from the network **105***a* or other network information generated by the integrated circuit **122**. A high optical power may be required for successful transmission of network data from the optical module **120***a* to the optical module **120***b*. Thus, when the LSLE_a signal has a logical high value, the processor can control the light source **124** to output light that may cause harm to an individual's eyes if they were exposed to the light.

However, when the LSLE_a signal has a logical low value, the integrated circuit **122** can respond by turning off the light source **124**. That is, a logical low value of the LSLE_a signal can cause the integrated circuit **122** to disable the light source **124**. In some implementations, the LSLE_a signal also can be modulated. The integrated circuit **122** can respond to the modulation of the LSLE_a signal by controlling the light source **124** to modulate the light output. In some implementations, the modulation pattern of the light source **124** can be configured to achieve a desired average optical power output of the light source **124**. For example, the light source **124** can be modulated to reduce the pulse width or duty cycle of the output of the light source **124**, so that the light output is safe for a human observer whose eyes are exposed to the light output. In some other implementations, in response to a low LSLE_a signal, the integrated circuit **122** causes the light source **124** to output a modulation pattern without the need for the LSLE_a signal to be modulated.

The light detector **126** receives an optical input signal, such as the Data_**2** signal generated by the optical module **120***b* shown in FIG. **1**A. The light detector **126** can detect a presence or absence of the Data_**2** signal, and transmits a signal corresponding to this presence or absence to the integrated circuit **122**. For example, the light detector **126** can output a digital signal to the integrated circuit **122**, with a logical high voltage indicating that the Data_**2** signal is present and a logical low voltage indicating that the Data_**2** signal is absent. This information can become the LSOD_a signal or can be used by the integrated circuit **122** to generate the LSOD_a signal. In some other implementations, the light detector **126** is configured to generate the LSOD_a signal (or another signal used as data to inform the generator of the LSOD_a signal), based on the presence or absence of another out-of-band optical signal received over the optical link. In some other implementations, the light detector **126** or the integrated circuit **122** outputs the LSOD_a signal based on a low-pass filtered version of the signal generated by the light detector **126** in response to the receipt of the Data_**2** signal.

In some implementations, the light detector **126** outputs an electrical signal to the integrated circuit **122** corresponding to the optical Data_**2** signal. The integrated circuit **122** can then decode the data signal. In some other implementations, the light detector **126** decodes the Data_**2** signal and relays the decoded signal to the integrated circuit **122**.

The LSOD_a signal indicates a presence or absence of an optical signal received by the optical module **120***a*, such as the Data_**2** signal or an out-of-band optical signal, indicating that the fiber optic cable is connected. For example, when the optical module **120***b* shown in FIG. **1**A is transmitting network data via the Data_**2** signal, the Data_**2** signal is detected by the light detector **126**. Similarly, the light detector can also detect an out-of-band signal transmitted by the optical module **120***b*, even if no network data is transmitted. In some implementations, the light detector **126** responds by generating an appropriate LSOD_a signal. As described above, the LSOD_a signal can have a logical high value when the Data_**2** signal or out-of-band signal is present. The integrated circuit **122** can determine that the LSOD_a signal should be high based on the detection of a predetermined modulation pattern of the out-of-band signal by the light detector **126**. In other implementations, the integrated circuit **122** can determine that the LSOD_a signal should be high based on the duty cycle of the Data_**2** signal detected by the light detector **126**. For example, the integrated circuit **122** can determine that the optical link is active if the duty cycle of the Data_**2** signal meets a minimum threshold. The LSOD_a signal remains at a logical high voltage as long as the Data_**2** signal is detected by the light detector **126**. Such detection logic prevents the light detector **126** or the integrated circuit **122** from falsely interpreting stray ambient light or light from a technician's flashlight, e.g., as a proper cable connection. In other implementations, the processor can determine that the LSOD_a signal should be high based on the strength of the Data_**2** signal detected by the light detector. In other implementations, the signal detected by the light detector may also be low pass filtered, to check if, on average, there is a stream of digital signals being received by the light detector.

When the Data_**2** signal or out-of-band signal is no longer detected, the LSOD_a signal generated by the integrated circuit **122** or by the light detector **126** changes to a logical low value, indicating the optical link is inactive. For example, if the fiber optic cable carrying the Data_**2** signal is disconnected from the optical module **120***a*, the light detector **126** will not detect the signal. Similarly, if the fiber optic cable is disconnected from its other end (i.e., from the optical module **120***b*), the light detector **126** will also fail to detect the Data_**2** signal. Thus, any disconnection of the fiber optic cable will result in a logical low voltage on the LSOD_a signal.

The logic device **112** of the controller **110***a* receives the LSOD_a signal via the input interconnect **116**, and responds by outputting an appropriate LSLE_a signal on the output interconnect **114**. The disconnection of the fiber optic cable may result in the eyes of an individual being exposed to harmful light, as discussed above. The logic device **112** can therefore respond to a fiber optic cable disconnection (i.e., a loss of the Data_**2** signal and corresponding logical low voltage on the LSOD_a signal) in a manner that reduces the risk of harm that may be caused by light escaping due to the disconnected cable. For example, the logic device **112**, can modulate the voltage on the output interconnect **114**. The integrated circuit **122** will detect the modulated voltage on the LSLE_a signal and will respond by causing the light source to output light modulated at a reduced average optical power that is safe for human eyes. In some other implementations, the logic device **112** can output a logical low voltage on the voltage interconnect **114**. The processor responds by turning off the light source **124** or modulating the output of the light source **124** at a low duty cycle, so that the light source **124** will not output light at dangerously high power levels while the fiber optic cable is disconnected.

FIG. **1**C is a state transition diagram **180** implemented by the controller **110***a* shown in FIG. **1**B, according to an illustrative implementation. The input to the controller **110***a* is the LSOD_a signal, which is received on the input interconnect **116**. The controller responds to the input by applying an appropriate voltage to the output interconnect **114** (i.e., the LSLE_a signal). The controller starts in the "safety state" **182**, in which the LSLE_a signal is logical low voltage or is modulated. The LSLE_a signal can be detected by the integrated circuit **122**, which can respond by turning off the light source in response to a logical low signal or reducing the average optical power of the light source to a level safe for human eyes in response to the low or modulated LSLE_a signal. For example, the light source **124** can be controlled to output an optical signal with a relatively small pulse width and duty cycle. The controller **110***a* remains in state **182** as long as the received LSOD_a signal has a logical low value, indicating a cable disconnection. Therefore, while the fiber optic cable is disconnected and individuals are potentially exposed to light from the light source **124**, the LSLE_a signal is modulated or kept at a low logical value to cause the light source **124** to emit light at a safe average optical power.

The controller **110***a* can transition to the "transmission state" **184** in response to receiving a logical high voltage on the LSOD_a signal or multiple pulses (N) with a logical high voltage on the LSOD_a signal. The high value of LSOD_a indicates that the cable connection has been restored. Therefore it is safe to increase the optical power of the light source **124**, and the controller **110***a* outputs a logical high value on LSLE_a, enabling the light source **124** to operate at an increased average optical power. The controller **110***a* remains in state **184** as long as the LSOD_a signal remains high (i.e., as long as the fiber optic cable is safely connected). The controller **110***a* transitions back to the safety state **182** when the LSOD_a signal takes on a logical low value, which indicates that the cable has again been disconnected.

FIG. **2**A is a block diagram of an alternative example optical link **200**, according to an illustrative implementation. The optical link **200** can be used to reduce the risk of eye damage to an individual who is exposed to light sources of the optical link **200**. Relative to the optical link **100** shown in FIG. **1**A, the optical link **200** includes additional failsafe features to further reduce the risk of harm potentially caused to individuals exposed to light emitted at an unsafe average optical power. For example, the optical link **200** includes two parallel transmit and receive channels, as well as a sense input for verifying signal values.

Like the optical link **100** shown in FIG. **1**A, the optical link **200** can represent a communication channel of a computer network. The optical link **200** includes a first controller **210***a* in communication with a first optical module **220***a*. A second controller **210***b* communicates with a second optical module **220***b*. Network data, such as data from the networks **205***a* and **205***b*, can be exchanged between the first optical module **220***a* and the second optical module **220***b*.

The networks **205***a* and **205***b* can include computer networks such as portions of the Internet, personal, local, metro, wide or other area networks, intranets, satellite networks, and other communication networks such as voice or data mobile phone communication networks. In some implementations, the networks **205***a* and **205***b* can include servers in one or more data centers, and the optical link **200** can represent a communication channel within or between the data centers. For example, the optical modules **220***a* and **220***b* can be included in network interface cards of respective servers in the data centers or in various switches, hubs, or routers in the data centers. The optical module **220***a* is configured to output two optical signals, shown as "Data_**0**" and "Data_**1**" in FIG. **2**A, to the optical module **220***b*. The optical module **220***b* outputs the optical signals shown as "Data_**2**" and "Data_**3**," which are received by the optical module **220***a*.

In some implementations, the optical signals Data_**0**, Data_**1**, Data_**2**, and Data_**3** are transmitted over fiber optic cables connected to respective input and output ports of the optical modules **220***a* and **220***b*. In some implementations, the Data_**0** and Data_**2** signals are carried by a single fiber optic cable, and the Data_**1** and Data_**3** signals are carried by a second fiber optic cable. As discussed above, optical signals may be harmful to an individual whose eyes are exposed to the optical signal. The optical power required to reliably transmit information between the optical module **220***a* and **220***b* may be relatively high to compensate for dispersion effects and optical noise within the fiber optic cables, as well as compensate for electrical noise at the receiver. If a fiber optic cable is disconnected, individuals in the vicinity of the optical link **200** can be exposed to the light, and the high optical power of the light may cause damage to the eyes of those individuals.

To reduce the risk of eye damage, the controllers **210***a* and **210***b* can implement control algorithms that prevent their respective optical modules **220***a* and **220***b* from outputting unsafe light levels in circumstances where individuals may be potentially exposed to the light (e.g., due to a disconnected fiber optic cable). The controller **210***a* receives two optical detection signals, shown as LSOD_a**0** and LSOD_a**1**, from the optical module **220***a* and outputs two respective enable signals, shown as LSLE_a**0** and LSLE_a**1**, that are received by the optical module **220***a*. Likewise, controller **210***b* receives the optical detection signals LSOD_b**0** and LSOD_b**1** from the optical module **220***b* and outputs the enable signals LSLE_b**0** and LSLE_b**1**, which is received by the optical module **220***b*. In some implementations, the respective LSLE and LSOD signals are digital signals whose voltages correspond to logic levels. The details of the algorithm implemented by the controllers **210***a* and **210***b* is described further below in connection with FIGS. **2**B-**2**D.

FIG. **2**B is a block diagram showing a controller **210***a* and an optical module **220***a* of the optical link **200** shown in FIG. **2**A, according to an illustrative implementation. The controller **210***a* includes a logic device **212**, output interconnects **214** and **215**, and input interconnects **216** and **217**. The logic device **212** receives the LSOD_a**0** input signal from the input interconnect **216** and receives the LSOD_a**1** input signal from the input interconnect **217**. The logic device **212** generates a voltage corresponding to the LSLE_a**0** signal and outputs the voltage on the output interconnect **214**. The logic device **212** generates a voltage corresponding to the LSLE_a**1** signal and outputs the voltage on the output interconnect **215**.

In some implementations, the logic device **212** may be implemented as special purpose logic circuitry, FPGA or an ASIC. In other implementations, the logic device **212** may be one or more general purpose processors configured to perform the processes disclosed herein

The optical module **220***a* includes an integrated circuit **222**, light sources **224** and **225**, and light detectors **226** and **227**. The integrated circuit **222** can communicate with the network **205***a*, for example to receive network packets to be transmitted to another network node by the optical module **220***a* or to forward packets intended for other nodes on the network **205***a*. For example, the integrated circuit **222** may be included in, or may be communicatively coupled to, a NIC or any other interface device configured to transmit and receive information to and from the network **205***a*. The integrated circuit **222** controls the light sources **224** and **225** to output the optical Data_**0** and Data_**1** signals, respectively, which can be transmitted to another optical module such as the optical module **220***b* shown in FIG. **2**A. In some implementations, the light sources **224** and **225** are lasers whose output can be controlled to correspond to the information encoded in the Data_**0** and Data_**1** signals. Suitable lasers include typical seminconductor lasers found in traditional fiber optic communication devices. The integrated circuit **222** controls the light sources **224** and **225** to generate the Data_**0** and Data_**1** signals. The light sources **224** and **225** can also include lenses or other focusing devices to collimate light. Such collimation increases the efficiency with which the optical signal is introduced into a fiber optic cable, but increases the risk to the human eye. In some implementations, the light sources **224** and **225** are capable of outputting optical signals having high average optical power that may harm an individual whose eyes are exposed to the optical signal.

The integrated circuit **222** can use the LSLE_a**0** signal as an enable input for the light source **224**. For example, when the LSLE_a**0** signal has a logical high value, the integrated circuit **222** can control the light source **224** to transmit network data to the optical module **220***b* via the Data_**0** signal. The Data_**0** signal can correspond to network packets received from the network **205***a* or other network information generated by the integrated circuit **222**. A high optical power may be required for successful and/or reliable transmission of network data from the optical module **220***a* to the optical module. Thus, when the LSLE_a signal has a logical high value, the processor can control the light source **224** to output light that may cause harm to an individual if the eye of the individual were exposed to the light.

However, when the LSLE_a**0** signal has a logical low value, the integrated circuit **222** can respond by refraining from transmitting data and reducing the power output of the laser to substantially eliminate the risk of eye injury. In some implementations, the integrated circuit **222** responds by turning off the light source **224**. In some other implementations, the optical power of the light source **224** can be reduced by modulating its output to have a reduced intensity or duty cycle. For example, the light source **224** can be modulated to reduce the pulse width or duty cycle of the output of the light source **224**, so that the light output is safe for an individual's eyes which could be exposed to the light source output.

Similarly, the LSLE_a**1** signal acts as an enable input for the light source **225**. The logical high, logical low, or modulated value of the LSLE_a**1** signal can cause the integrated circuit **222** to control the light source **225** accordingly. For example, a logical low or modulated value of LSLE_a**1** can cause the integrated circuit **222** to disable the light source **225** or otherwise cause it to reduce its average power output. A logical high value of LSLE_a**1** can cause the integrated circuit **222** to allow the light source **225** to transmit network information at a high optical power.

In some implementations, in response to receiving an LSLE_a**0** or LSLE_a**1** signal having a logical low value or a modulated value, the integrated circuit **222** ceases outputting data to one or both of the light sources **224** and **225**.

The light detector **226** receives an optical input signal, such as the Data_**2** signal generated by the optical module **220***b* shown in FIG. **2**A. The light detector **226** can detect a presence or absence of the Data_**2** signal, and transmits a signal corresponding to this presence or absence to the integrated circuit **222**. For example, the light detector **226** can output a digital signal to the integrated circuit **222**, with a logical high voltage indicating that the Data_**2** signal is present and a logical low voltage indicating that the Data_**2** signal is absent. This information can become the LSOD_a**0** signal or can be used by the integrated circuit **222** to generate the LSOD_a**0** signal. In some other implementations, the light detector **226** is configured to generate the LSOD_a**0** signal, (or another signal used as data to inform the generator of the LSOD_a**0** signal), based on the presence or absence of another out-of-band optical signal received over the optical link. For example, the out-of-band signal can be used to indicate that the optical link is still active in instances in which no data is transmitted over the optical link.

In some implementations, the light detector **226** outputs an electrical signal to the integrated circuit **222** corresponding to the optical Data_**2** signal. The integrated circuit **222** can then decode the data signal. In some other implementations, the light detector **226** decodes the Data_**2** signal and relays the decoded signal to the integrated circuit **222**. The light detector **227** behaves in a manner similar to the light detector **226**. For example, the light detector **227** receives the Data_**3** signal or another out-of-band optical signal, relays the information to the integrated circuit **222**, and generates (or helps to generate) the LSOD_a**1** signal.

In some implementations, the LSOD_a**0** and LSOD_a**1** signals are generated based on a low-pass filtered version of a signal output by the light detector responsive to the received data or out-of-band signals.

The LSOD_a**0** signal indicates a presence or absence of an optical signal received by the optical module **220***a*, such as the Data_**2** signal or another out-of-band signal. For example, when the optical module **220***b* shown in FIG. **2**A is transmitting network data via the Data_**2** signal, the Data_**2** signal is detected by the light detector **226**. Alternatively, the light detector **226** may receive the out-of-band signal as an indication that the optical link is active but that no data is being transmitted. In some implementations, the light detector **226** responds by generating an appropriate LSOD_a**0** signal. As described above, the LSOD_a**0** signal can have a logical high value when the Data_**2** signal is present. In other implementations, the light detector **226** transmits the network information encoded in the Data_**2** signal to the integrated circuit **222**, and the integrated circuit **222** generates the appropriate LSOD_a**0** signal. The LSOD_a**0** signal remains at a logical high voltage as long as the Data_**2** signal is detected by the light detector **226**.

When the Data_**2** signal (or out-of-band signal) is no longer detected, the LSOD_a**0** signal generated by the integrated circuit **222** or by the light detector **226** changes to a logical low value, indicating the Data_**2** signal is absent. For example, if the fiber optic cable carrying the Data_**2** signal is disconnected from the optical module **220***a*, the light detector **226** will not detect the signal. Similarly, if the fiber optic cable is disconnected from its other end (i.e., from the optical module **220***b*), the light detector **226** will also fail to detect the Data_**2** signal. Thus, any disconnection of the fiber optic cable will result in a logical low voltage on the LSOD_a**0** signal. The LSOD_a**1** signal similarly is used to indicate a presence or absence of the Data_**3** signal. A logical low value for LSOD_a**1** indicates that the Data_**3** signal is absent, for example due to a disconnection of the fiber optic cable carrying the Data_**3** signal.

In some implementations, the light sources **224** and **225** are used to transmit identical network traffic in parallel with each other. This redundancy can help to avoid single points of failure in that can be present in systems without redundancy, such as the optical link **100** shown in FIG. **1**A. The optical module **220***b* can be used in the same manner, such that the signals Data_**2** and Data_**3** received by the light detectors **226** and **227**, respectively, are intended to be identical copies. In some implementations, the parallel data signals can be achieved in a single fiber optic cable, for example by using wavelength division multiplexing. In other implementations, separate cables can be used (e.g., one cable for Data_**0** and Data_**2**, and one cable for Data_**1** and Data_**3**).

As in the example of FIGS. **1**A-**1**C, the logic device **212** can respond to a fiber optic cable disconnection (i.e., a loss of the Data_**2** or Data_**3** signal and corresponding logical low voltage on the LSOD_a**0** or LSOD_a**1** signal, which is applied on the input interconnects **216** and **217**, respectively) in a manner that reduces the risk of harm that may be caused by light escaping due to the disconnected cable. By using redundant parallel channels, the logic device **212** is able to eliminate single points of failure that are present in the optical link of FIG. **1**A. For example, without redundant parallel channels (i.e., without the channels carrying the Data_**1** and Data_**3** optical signals), one single point of failure can occur when the LSOD_a**0** signal becomes "stuck" at a logical high value. The LSOD_a**0** signal is considered "stuck" when the voltage applied to the input interconnect **217** is a logical high voltage when the integrated circuit **222** is generating a logical low voltage for LSOD_a**0**. If this type of failure occurs, the logic device **212** may erroneously determine that the fiber optic cable is connected. As a result, LSLE_a**0** will remain high, potentially allowing light to harm an individual while the cable is disconnected. Including parallel channels carrying the Data_**1** and Data_**3** signals, along with a parallel detection signal (i.e., LSOD_a**1**), can prevent such a failure. For example, the logic device **212** can determine the state of the LSOD_a**0** and LSOD_a**1** signals by measuring the voltages on the input interconnects **216** and **217**. The logic device can then determine whether one of the LSOD_a**0** or LSOD_a**1** signals is "stuck" in a logical high state by determining by whether the LSOD_a**0** and LSOD_a**1** signals have identical values. Because the Data_**2** and Data_**3** signals received by the optical module **220***a* are identical, the LSOD_a**0** and LSOD_a**1** signals generated by the integrated circuit **222** should also be identical under normal operating conditions. Therefore, if these signals do not match, the logic device **212** can determine that one of the signals is "stuck" at a logical high voltage. To ensure that such a failure does not result in harm to an individual in the vicinity of a potentially disconnected optical cable, the logic device **212** can output logical high voltages on output interconnects **214** and **216** (corresponding to LSLE_a**0** and LSLE_a**1**) only if LSOD_a**0** and LSOD_a**1** are both logical high, because a mismatch would indicate a stuck pin.

FIG. **2**C is a block diagram showing an alternative configuration for the controller **210** and the optical module **220***a* of the optical link shown in FIG. **2**A, according to an illustrative implementation. The optical module **220***a* includes the integrated circuit **222**, the light source **224**, and the light detector **226**, but does not include the additional redundant parallel optical link shown in FIG. **2**B and its associated components, such as the light source **225** and the light detector **227**. The controller **210***a* includes the logic device **212** as well as input interconnects **216**, **218**, and **219** and an output interconnect **214**. The logic device **212**, integrated circuit **222**, light source **224**, and light detector **226** shown in FIG. **2**C perform the same functions as described above in connection with FIG. **2**B.

Also shown in FIG. **2**C is an electrical connection formed between the input interconnect **218** and the input to the optical module **220***a* that receives the LSLE_a input from the output interconnect **214**. The signal carried by this electrical connection is labeled LSLE_a'. A signal monitor **230** receives the Data_**0** signal as an input and generates the LSLE_a" signal as an output, which is received by the controller **210** at the input interconnect **219**. The addition of the LSLEa' and LSLE_a" signals can eliminate a second single point of failure present in the optical link **100** shown in FIGS. **1**A and **1**B.

For example, a second single point of failure occurs when the LSLE_a input is erroneously "stuck" at a logical high voltage. This failure condition is dangerous because it will cause the light source **224** to continue to output unsafe levels of light even if the fiber optic cable is disconnected. By measuring the LSLE_a input to the optical module **220** and/or measuring the optical signal Data_**0**, the logic device can determine whether this failure has occurred. To measure the LSLE_a signal, an electrical connection is formed between the input interconnect **218** and the input to the optical module **220***a* that receives the LSLE_a input from the output interconnect **214**. In some implementations, the logic device **212** compares the voltage output on the output interconnect **214** to the voltage received at the input interconnect **218**. If the controller **210** and the optical module **220***a* are operating correctly, these signals should be substantially the same, because the voltage applied to the output interconnect **214** is not modified before being received as LSLE_a' on the input interconnect **218**. However, in some circumstances, these voltages may not match. For example, the LSLE_a input to the optical module **220***a* may accidentally come into contact with another electrical component of the system, which could cause erroneous voltages on the LSLE_a input to the optical module **220***a*. Therefore, if the voltages on the output interconnect **214** and the input interconnect **218** do not match, the logic device **212** determines that a failure condition has occurred, and controls the integrated circuit **222** to turn off the light source **224**, thereby preventing harm to individuals whose eyes may be exposed to the light output.

Alternatively, or additionally, the logic device **212** may determine the LSLE_a signal is "stuck" at a logical high voltage by using the output from the monitor **230**. The monitor **230** can receive the optical output of the light source **224**, and can generate that LSLE_a" signal in response. For example, the LSLE_a" signal can be a digital voltage indicating a presence or absence of the Data_**0** signal or another out-of-band signal. A logical high value of LSLE_a" can indicate that the Data_**0** signal or out of band signal is present. In some implementations, the monitor **230** detects the output of the light source **224** without substantially altering the signal. For example, the Data_**0** signal may be carried to the monitor **230** by a different fiber than is used to transmit the Data_**0** signal to the optical module **220***b* shown in FIG. **2**A.

The logic device **212** compares the voltage output on the output interconnect **214** to the voltage received at the input interconnect **219**. If the controller **210** and the optical module **220***a* are operating correctly, these signals should be substantially the same. For example, the monitor **230** should only detect a signal from the light source **224** and output a logical high voltage when the LSLE_a output is also high to enable the light source **224**. However, as discussed above, these voltages may not match in some circumstances when the LSLE_a signal becomes "stuck" at a high voltage. Therefore, if the voltages on the output interconnect **214** and the input interconnect **219** do not match, the logic device **212** determines that a failure condition has occurred, and controls the integrated circuit **222** to turn of the light source **224**, thereby preventing harm to individuals whose eyes may be exposed to the light output.

In some implementations, the enable feedback configuration shown in FIG. **2**C can be used in conjunction with the parallel channels shown in FIG. **2**B. For example, the logic device **212** could receive feedback inputs from both the LSLE_a**0** and LSLE_a**1** signals, and could use the feedback signals to determine whether one of the LSLE signals is "stuck" at a logical high voltage. In some implementations, the integrated circuit **222** can turn off both light sources **224** and **225** in response to a determination by the logic device **212** that either LSLE_a**0** or LSLE_a**1** is "stuck."

FIG. **2**D is a state transition diagram **280** implemented by the controller **210***a* shown in FIG. **2**B, according to an illustrative implementation. The input to the controller **210***a* are the LSOD_a**0**, LSOD_a**1**, LSLE_a', and LSLE_a" signals, which are received on the input interconnects **216**, **217**, **218**, and **219**, respectively. The controller responds to the input by applying appropriate voltages to the output interconnects **214** and **215** (i.e., the LSLE_a**0** and LSLE_a**1** signals). The enable signals are intended to be redundant, so the controller always outputs the same value on both output interconnects **214** and **215**.

The controller starts in the "safety state" **282**, in which the LSLE_a**0** and LSLE_a**1** signals are either logical low voltages or modulated. The LSLE_a**0** and LSLE_a**1** signals can be detected by the integrated circuit **222**, which can respond by turning off the respective light source in response to a logical low signal or reducing the average optical power of the respective light source to a level safe for human eyes in response to a modulation pattern. For example, light sources **224** and **225** can be controlled to output optical signals with relatively small pulse widths and duty cycles to reduce their average optical power. The controller **210***a* remains in state **282** as long as the either of the received LSOD_a**0** and LSOD_a**1** signals has a logical low value, indicating a cable disconnection, or if there is a mismatch between the LSLE_a, LSLE_a', and LSLE_a" signals, indicating a "stuck" enable pin. Therefore, while the fiber optic cable is disconnected or an enable pin is "stuck" at a logical high value, the LSLE_a**0** and LSLE_a**1** signals are maintained either at logical low values to turn the light sources **224** and **225** off, or are modulated to cause the light sources **224** and **225** to emit light at a safe average optical power.

The controller **210***a* transitions to the "transmission state" **284** in response to receiving a logical high voltage (or pulses of high voltages) on both the LSOD_a**0** and LSOD_a**1** signals, as well as a match between the LSLE_a, LSLE_a', and LSLE_a" signals. The high values of LSOD_a**0** and LSOD_a**1** indicate that the cable connection has been restored and the match between the LSLE_a, LSLE_a', and LSLE_a" signals indicates that there is not a "stuck" enable pin. Therefore it is safe to increase the optical power of the light sources **224** and **225**, and the controller **210***a* outputs a logical high value on LSLE_a**0** and LSLE_a**1**, enabling the light sources **224** and **225** to operate at an increased average optical power. The controller **210***a* remains in state **284** as long as the LSOD_a**0** and LSOD_a**1** signals remain high (i.e., as long as the fiber optic cable is safely connected) and the values of LSLE_a, LSLE_a', and LSLE_a" are matching. The controller **210***a* transitions back to the "safety state" **282** when either of the LSOD_a**0** or LSOD_a**1** signals takes on a logical low value, which indicates that the cable has again been disconnected, or when there is a mismatch between the logical values of LSLE_a, LSLE_a', and LSLE_a", indicating a "stuck" pin.

FIG. **3** is a flow diagram of a process **300** for operating an optical transceiver, according to an illustrative implementation. The process **300** is similar to the algorithm implemented by the controller **110***a* shown in FIG. **1**B. The process **300** includes determining a presence or absence of a first signal (stage **305**). In some implementations, the first signal is an optical signal received from another optical transceiver. A light detector can be used to determine the presence or absence of the first signal. In some implementations, the optical signal is a data signal output by another transceiver. In some other implementations, the optical signal is an out-of-band signal output by the other transceiver. The out-of-band signal can be transmitted even when data is not actively being transmitted by the transceiver, thereby avoiding the receiving transceiver from mistakenly detecting a false disconnection when traffic rates slow. In some implementations, the light detector can output a signal indicative of the presence or absence of the first signal. The absence of the first signal can indicate that a fiber optic cable carrying the first signal has been disconnected from at least one end of the communication link.

The process **300** includes outputting a second signal at a decreased power, responsive to determining an absence of the first signal (stage **310**). In some implementations, the second signal is an optical signal and the decreased power is an average optical power that is not harmful to the eyes of a human observer. Thus, the decreased optical power can be used for the second signal when the first signal is determined to be absent, indicating a possible cable disconnection. In some implementations, it can be advantageous to output an optical signal having decreased average optical power instead of turning off the light source. For example, the low power signal can allow a receiving optical module to determine when the connection has been restored. If no signal were output, the receiving optical module would not be able to determine that the connection is restored. Because a disconnected cable leaves light from the optical transceiver exposed, it can be desirable to transmit a signal at a decreased power while the cable is disconnected, in order to protect the eyes of individuals who may be exposed to the light. The signal can be transmitted at a decreased power by reducing the intensity and/or the duty cycle of the optical signal.

The process **300** includes outputting the second signal at an increased power, responsive to determining a presence of the first signal (stage **315**). In some implementations, the first signal is detected by monitoring the direct output of a light detector. In some other implementations, the first signal is detected by measuring a low-pass filtered version of the light detector output. In some other implementations, the first signal is detected by detecting a configurable modulation pattern in the light detector output corresponding to a modulation pattern known to be implemented by a transceiver when operating in a safe mode.

The increased power may be an optical power that would be harmful to the eyes of a human observer. However, if the first signal is determined to be present, then the cable carrying the signal is connected to the transceiver and the optical signal will not be exposed. An increased optical power can therefore be used safely. In some implementations, the increased optical power may be selected based on a desired signal quality for a communication link. For example, the optical transceiver may output a signal having an optical power sufficiently high to overcome optical noise within the link.

Implementations of the subject matter and the operations described in this specification can be implemented in digital electronic circuitry, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. The subject matter described in this specification can be implemented as one or more computer programs, i.e., one or more modules of computer program instructions, encoded on one or more computer storage media for execution by, or to control the operation of, data processing apparatus.

A computer readable medium can be, or be included in, a computer-readable storage device, a computer-readable storage substrate, a random or serial access memory array or device, or a combination of one or more of them. Moreover, while a computer readable medium is not a propagated signal, a computer storage medium can be a source or destination of computer program instructions encoded in an artificially-generated propagated signal. The computer storage medium can also be, or be included in, one or more separate components or media (e.g., multiple CDs, disks, or other storage devices). Accordingly, the computer readable medium is tangible and non-transitory.

The operations described in this specification can be performed by a data processing apparatus on data stored on one or more computer-readable storage devices or received from other sources. The term "data processing apparatus" or "computing device" encompasses all kinds of apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, a system on a chip, or multiple ones, or combinations of the foregoing The apparatus can include special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC. The apparatus can also include, in addition to hardware, code that creates an execution environment for the computer program in question, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, a cross-platform runtime environment, a virtual machine, or a combination of one or more of them. The apparatus and execution environment can realize various different computing model infrastructures, such as web services, distributed computing and grid computing infrastructures.

A computer program (also known as a program, software, software application, script, or code) can be written in any form of programming language, including compiled or interpreted languages, declarative or procedural languages, and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, object, or other unit suitable for use in a computing environment. A computer program may, but need not, correspond to a file in a file system. A program can be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub-programs, or portions of code). A computer program can be deployed to be executed on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communication network.

Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of computer. Generally, a processor will receive instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a processor for performing actions in accordance with instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data, e.g., magnetic, magneto-optical disks, or optical disks. However, a computer need not have such devices.

While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any inventions or of what may be claimed, but rather as descriptions of features specific to particular implementations of particular inventions. Certain features described in this specification in the context of separate implementations can also be implemented in combination in a single implementation. Conversely, various features described in the context of a single implementation can also be implemented in multiple implementations separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described program components and systems can generally be integrated in a single product or packaged into multiple products.

Thus, particular implementations of the subject matter have been described. Other implementations are within the scope of the following claims. In some cases, the actions recited in the claims can be performed in a different order and still achieve desirable results. In addition, the processes depicted in the accompanying figures do not necessarily require the particular order shown, or sequential order, to achieve desirable results. In certain implementations, multitasking and parallel processing may be advantageous.

What is claimed is:

**1**. An optical transceiver, comprising:

an optical module configured to output a first optical signal;

a first photodetector configured to output a signal indicative of a presence or absence of a second optical signal;

a second photodetector configured to output a signal indicative of a presence or absence of a third optical signal; and

a controller coupled to the optical module and the first photodetector, and configured to control the output of the optical module, wherein:

in response to a determination by the controller that an output of the first photodetector indicates the second optical signal is absent, the controller controls the optical module to output the first signal at a decreased average optical power;

in response to a determination by the controller that the output of the first photodetector indicates the second optical signal is present, the controller controls the optical module to output the first optical signal at an increased average optical power; and

in response to a determination of a mismatch between the outputs of the first photodetector and the second photodetector, the controller controls the optical module to output the first optical signal at the decreased average optical power.

**2**. The optical transceiver of claim **1**, wherein the optical module includes a laser for generating the first optical signal.

**3**. The optical transceiver of claim **2**, further comprising a lens coupled to the laser and configured to collimate light output by the laser.

**4**. The optical transceiver of claim **1**, wherein the decreased average optical power is sufficiently low to be substantially harmless to the eye of a human observer.

**5**. The optical transceiver of claim **1**, wherein the controller is further configured to:

control the optical module to output the first signal at the decreased average optical power by applying a logical low voltage on a first output pin of the controller coupled to the optical module; and

control the optical module to output the first signal at the increased average optical power by applying a logical high voltage on the first output pin of the controller coupled to the optical module.

**6**. The optical transceiver of claim **5**, wherein the controller is further configured to:

determine a match or mismatch between the voltage applied to the first output pin of the controller and a voltage received from the controller by the optical module; and

control the optical module to output the first optical signal at the decreased average optical power, responsive to determining a mismatch.

**7**. The optical transceiver of claim **5**, wherein the controller is further configured to:

control the optical module to output the first optical signal at the decreased average optical power, responsive to determining that the output of the first photodetector indicates the second optical signal is present and that the voltage applied to the first output pin is a logical low voltage.

**8**. A method for operating an optical transceiver, the method comprising:

outputting, by a photodetector of the optical transceiver, a signal indicative of a presence or absence of a first optical signal;

outputting, by the optical transceiver, a second optical signal at a decreased average optical power, responsive to a determination that the first optical signal is absent;

outputting, by the optical transceiver, the second optical signal at an increased average optical power, responsive to a determination that the first optical signal is present;

determining, by the optical transceiver, a presence or absence of a third optical signal;

determining, by the optical transceiver, a match or mismatch between the first optical signal and the third optical signal; and

outputting, by the optical transceiver, the second optical signal at the decreased average optical power, responsive to determining a mismatch.

**9**. The method of claim **8**, wherein outputting the second optical signal at a decreased average optical power comprises outputting the second optical signal such that the second optical signal is substantially harmless to the eye of a human observer.

**10**. The method of claim **8**, further comprising:

applying, by a controller of the optical transceiver, a logical low voltage on a first output pin coupled to an optical module of the optical transceiver to control the optical module to output the second optical signal at the decreased average optical power; and

applying, by the controller of the optical transceiver, a logical high voltage on the first output pin coupled to the optical module of the optical transceiver to control the optical module to output the second optical signal at the increased average optical power.

**11**. The method of claim **9**, further comprising:

determining, by the controller, a match or mismatch between the voltage applied on the first output pin and the voltage received from the controller by the optical module; and

controlling, by the controller, the optical module to output the second optical signal at the decreased average optical power, responsive to determining a mismatch.

**12**. An optical transceiver, comprising:

a light outputting means for outputting a first optical signal;

a first light detecting means for outputting a signal indicative of a presence or absence of a second optical signal;

a second light detecting means for outputting a signal indicative of a presence or absence of a third optical signal;

a signal analyzing means for analyzing the signal output by the light detecting means; and

a signal controlling means configured to:

control the light outputting means to output the first optical signal at a decreased average optical power, responsive to a determination by the signal analyzing means that the output of the light detecting means indicates the second optical signal is absent;

control the light outputting means to output the first optical signal at an increased average optical power, responsive to a determination by the signal analyzing means that the output of the light detecting means indicates the second optical signal is present;

control the light outputting means to output the first optical signal at the decreased average optical power, responsive to a determination of a mismatch between the outputs of the first light detecting means and the second light detecting means.

**13**. The optical transceiver of claim **12**, further comprising a focusing means optically coupled to the light outputting means to collimate light forming the first optical signal.

**14**. The optical transceiver of claim **12**, wherein the signal controlling means is further configured to:

control the light outputting means to output the first optical signal at the decreased average optical power by applying a logical low voltage on a first output pin coupled to the light outputting means; and

control the light outputting means to output the first optical signal at the increased average optical power by applying a logical high voltage on a first output pin coupled to the light outputting means.

**15**. The optical transceiver of claim **12**, wherein the signal controlling means is further configured to:

determine a match or mismatch between the voltage applied to the first output and a voltage received from the controlling means by the light outputting means; and

control the light outputting means to output the first optical signal at the decreased average optical power, responsive to determining a mismatch.

**16**. An optical transceiver, comprising:

an optical module configured to output a first optical signal;

a first photodetector configured to output a signal indicative of a presence or absence of a second optical signal matching a previously provided pattern; and

a controller coupled to the optical module and the first photodetector, and configured to control the output of the optical module, wherein:

in response to a determination by the controller that an output of the first photodetector indicates the second optical signal is absent, the controller controls the optical module to output the first signal at a decreased average optical power,

in response to a determination by the controller that the output of the first photodetector indicates the second optical signal is present, the controller controls the optical module to output the first optical signal at an increased average optical power, and

the controller is further configured to:

determine a match or mismatch between a voltage applied to a first output pin of the controller coupled to the optical module and a voltage received from the controller by the optical module; and

control the optical module to output the first optical signal at the decreased average optical power, responsive to determining a mismatch.

**17**. The optical transceiver of claim **16**, wherein the optical module includes a laser for generating the first optical signal.

**18**. The optical transceiver of claim **17**, further comprising a lens coupled to the laser and configured to collimate light output by the laser.

**19**. The optical transceiver of claim **16**, wherein the decreased average optical power is sufficiently low to be substantially harmless to the eye of a human observer.

**20**. The optical transceiver of claim **16**, wherein the controller is further configured to:

control the optical module to output the first signal at the decreased average optical power by applying a logical low voltage on the first output pin of the controller coupled to the optical module; and

control the optical module to output the first signal at the increased average optical power by applying a logical high voltage on the first output pin of the controller coupled to the optical module.

**21**. The optical transceiver of claim **20**, wherein the controller is further configured to:

control the optical module to output the first optical signal at the decreased average optical power, responsive to determining that the output of the first photodetector indicates the second optical signal is present and that the voltage applied to the first output pin is a logical low voltage.

**22**. A method for operating an optical transceiver, the method comprising:

outputting, by a photodetector of the optical transceiver, a signal indicative of a presence or absence of a first optical signal matching a previously provided pattern;

outputting, by the optical transceiver, a second optical signal at a decreased average optical power, responsive to a determination that the first optical signal is absent; and outputting, by the optical transceiver, the second optical signal at an increased average optical power, responsive to a determination that the first optical signal is present;

determining, by the controller, a match or mismatch between the voltage applied on a first output pin coupled to an optical module of the optical transceiver and a voltage received from the controller by the optical module of the optical transceiver; and

controlling, by the controller, the optical module to output the second optical signal at the decreased average optical power, responsive to determining a mismatch.

**23**. The method of claim **22**, wherein outputting the second optical signal at a decreased average optical power comprises outputting the second optical signal such that the second optical signal is substantially harmless to the eye of a human observer.

**24**. The method of claim **22**, further comprising:

applying, by a controller of the optical transceiver, a logical low voltage on the first output pin coupled to the optical module of the optical transceiver to control the optical module to output the second optical signal at the decreased average optical power; and

applying, by the controller of the optical transceiver, a logical high voltage on the first output pin coupled to the optical module of the optical transceiver to control the optical module to output the second optical signal at the increased average optical power.

**25**. An optical transceiver, comprising:

a light outputting means for outputting a first optical signal;

a light detecting means for outputting a signal indicative of a presence or absence of a second optical signal matching a previously provided pattern;

a signal analyzing means for analyzing the signal output by the light detecting means; and

a signal controlling means configured to:

control the light outputting means to output the first optical signal at a decreased average optical power, responsive to a determination by the signal analyzing means that the output of the light detecting means indicates the second optical signal is absent;

control the light outputting means to output the first optical signal at an increased average optical power, responsive to a determination by the signal analyzing means that the output of the light detecting means indicates the second optical signal is present;

determine a match or mismatch between a voltage applied to a first output pin coupled to the light outputting means and a voltage received from the controlling means by the light outputting means; and

control the light outputting means to output the first optical signal at the decreased average optical power, responsive to determining a mismatch.

**26**. The optical transceiver of claim **25**, further comprising a focusing means optically coupled to the light outputting means to collimate light forming the first optical signal.

**27**. The optical transceiver of claim **25**, wherein the signal controlling means is further configured to:

control the light outputting means to output the first optical signal at the decreased average optical power by applying a logical low voltage on the first output pin coupled to the light outputting means; and

control the light outputting means to output the first optical signal at the increased average optical power by applying a logical high voltage on the first output pin coupled to the light outputting means.

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